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Overcoating Lead-Based Paint on Bridges: An Overview of Different Coating Options

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This article outlines some of the more popular types of coatings employed in overcoating bridges having existing lead-based paints. It highlights the performance of four different coating types. The importance of coating adhesion, barrier properties, wetting, and penetration is surveyed as well as coating stresses in light of film thickness, chemistry, and weather-related phenomena.

Good surface preparation is conducive to good coating adhesion and anticipated service life. International surface preparation standards are clearly documented, and visual standards exist for abrasive-blasted steel; such factors assure contractors that all likely will bode well in a lead-abatement project. Matters become difficult, however, when surface preparation standards are unclear or when one deals with a nonstandard substrate having a multiple-layered system of a lead-based paint. This is the realm of "overcoating."

Overcoating is broadly defined as "spot cleaning and priming degraded areas, cleaning intact paint, and applying a lead-free system over the existing system."¹

The great appeal behind overcoating bridges is primarily cost reduction; there is no need to fully remove deteriorated lead-based paint systems and pay for full containment and higher hazardous waste disposal. Ultimately, however, life-cycle cost analysis usually shows that full lead removal is less expensive in the long term.

Background

Lead is a pervasive element that has been used successfully in bridge coatings for more than 100 years (Figure 1). Lead-based paints have also been used extensively to coat the externals

FIGURE 1

The Quebec Bridge is one of the largest overcoating projects in North America (8,000,000 ft² [743,200 m²]) and utilizes RAVCS chemistries for rust mitigation and overcoating. Photo courtesy of Termarust Technologies.



of water and oil storage tanks. In 1994, costs ranged from \$4 to \$13/ft² (0.09 m²) for abrasive blasting and full lead-based paint removal compared to \$2 to \$7/ft² for overcoating.² In 1997, SSPC: The Society for Protective Coatings conducted a survey in which the national costs were noted to average \$7.75 and \$4.50, respectively, for full removal and overcoating.³

Cost savings can also be accrued by zone painting (i.e., by paying particular attention to the worst areas and not the entire structure).

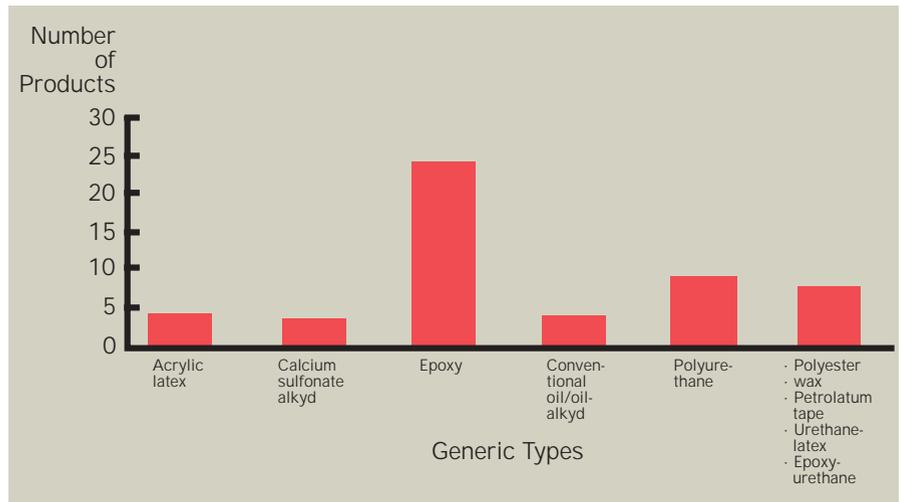
Difficulties in selecting an overcoat system arise from the generic type, age, and condition of the existing coating system; what type of surface preparation is best employed to assure good adhesion; what are compatible overcoat systems; and predictions of how long the new system will last.

Although overcoat systems are applied to lesser-prepared surfaces (including tight rust and existing soundly adhered coatings), careful preliminary work must be done in order to decide if overcoating is a viable techno-economic option. Kline and Corbett provide a comprehensive analysis of overcoating.⁴

Candidate overcoat systems include acrylic latexes, reacted alkaline viscolastic calcium sulfonate (RAVCS) penetrants and topcoats, epoxy high build mastics, penetrating epoxy primers, and moisture-cured urethanes. The person entrusted with selecting a system probably will seek ~15 years of satisfactory overcoating service with minimal maintenance. Not all coating systems are equal, however, and it is necessary to carefully weigh their features, benefits, and track records. Overcoat systems have failed prematurely because of unforeseen factors and inherent problems associated with the technology used.

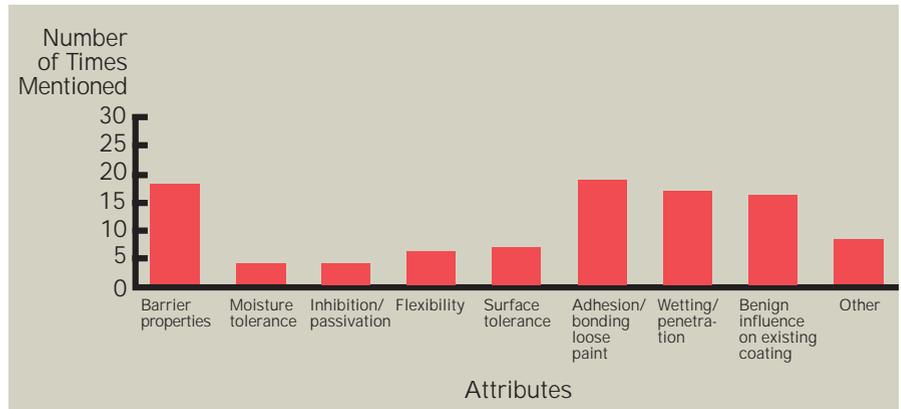
Even within a generic classification, coatings can perform with substantial differences, either because of formulation nuances or more obvious compositional differences. Aside from scruti-

FIGURE 2



Generic types of overcoating products reported in "Survey of Overcoating Products." Figures 2 through 6 originally published in "Survey of Overcoating Products," *Journal of Protective Coatings & Linings* (November 1993), pp. 102-104. © JPCL™. Reprinted with permission.

FIGURE 3



Useful mechanisms for overcoating.

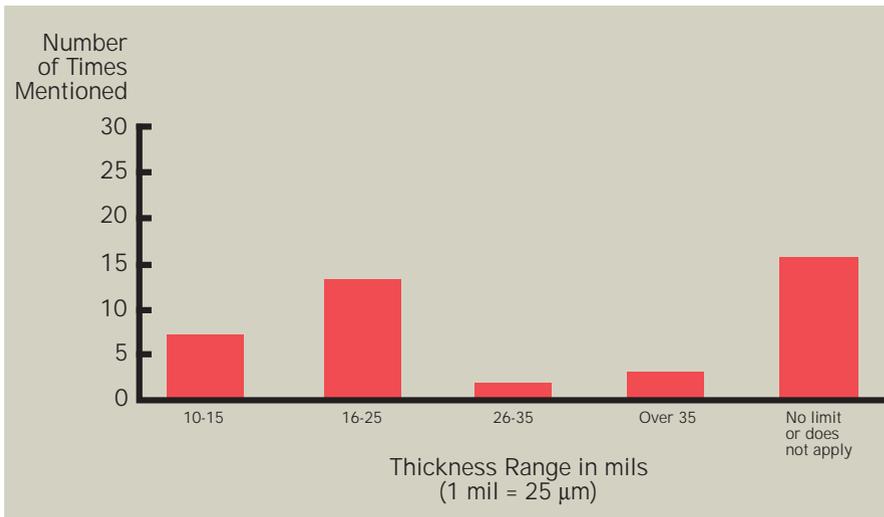
nizing a coating's touted performance, specifiers must occasionally sort the proverbial wheat from the chaff from aspersions cast in attempts to gain competitive advantage. Even after due diligence has been conducted in selecting an overcoat system, Forsgren states that overcoating can be a "hit or miss" technique and likens its present use to gambling.⁵

In 1993, Hower listed the generic types of products used for overcoating lead-based paint.¹ Two hundred coating companies were contacted and 49 products were described in the re-

sponses. Figures 2 through 6 summarize the results.

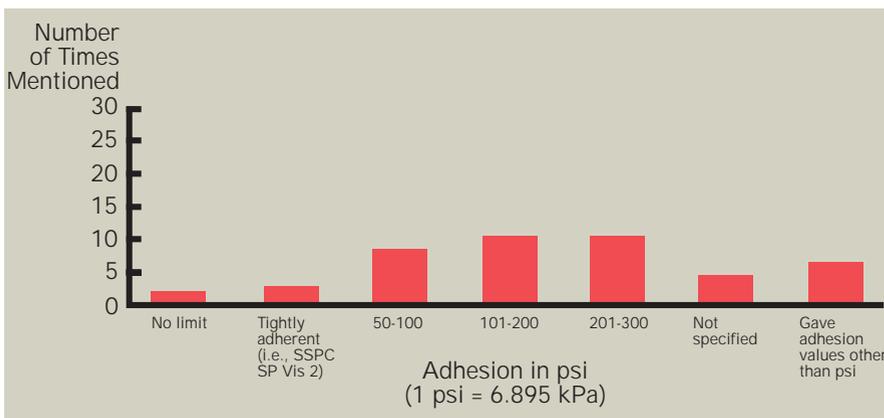
Epoxies accounted for about half the overcoating systems used (Figure 2). According to the survey, four dominant mechanisms gave good overcoating performance. They were, in order of descending importance: a) tenacious adhesion, b) good ability to wet and/or penetrate the surface, c) benign influence on the existing coating, including compatibility and imparting minimal stresses from solvent lifting or cure, and d) barrier properties for corrosion protection (Figure

FIGURE 4



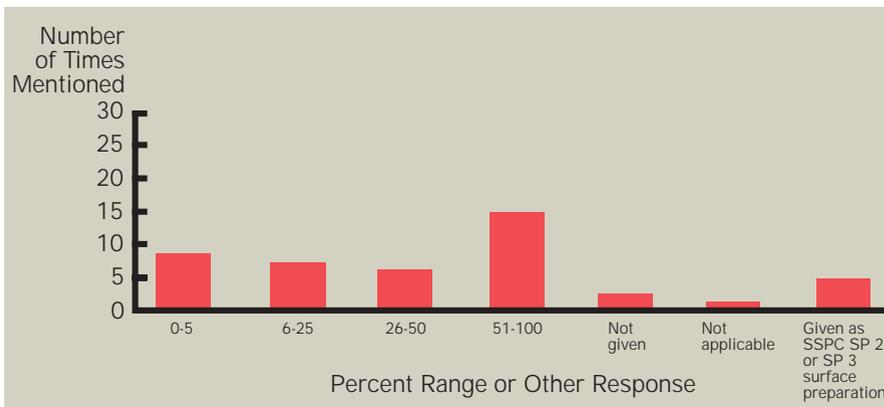
Maximum film thickness tolerable of existing coatings prior to overcoating.

FIGURE 5



Minimum adhesion levels of existing coatings.

FIGURE 6



Minimum percent rust on existing coated substrate before overcoating.

3). Other, less-cited overcoating attributes included flexibility, moisture tolerance, rust tolerance, and rust inhibition.

The companies' responses varied, but film thicknesses of existing coatings were considered to be satisfactory at 10 to 25 mils (254 to 635 μm) dry film thickness (DFT) (Figure 4). Also, the minimum acceptable adhesion values of old coatings (prior to overcoating) are noted as 100 to 200 psi (690 to 1,379 kPa) (Figure 5). Finally, the maximum percent rust on the existing coated substrate could be in the range of 51 to 100%, provided that the rust was tight.

SSPC's *Journal of Protective Coatings and Linings (JPCL)* survey was conducted nearly 1 decade ago, but to the best of the author's knowledge, no comparable survey has been taken since then and the data are considered reasonably current.

Overcoating: Key Requirements

FIELD TESTS

The primary requirements for field tests are as follows:

- Determine the approximate percentage of the total rusted area (SSPC Vis 2⁶).
- Test to determine if the existing coating contains lead.
- Observe the character of the rusted areas: light rust, moderate, or severe corrosion.
- Determine the condition of the steel under the existing coating. Use a SARA chemical stripper to remove the coating and determine if a profile exists or if mill scale is present.⁷
- Check the adhesion of the existing coating system (ASTM D3359⁸).
- Determine the total thickness and generic type of the existing coating.
- Estimate the serviceability or remaining life of the existing coating system and its ability to be repaired.
- Apply test patches (ASTM D5064⁹) of potential overcoat systems. Evaluate them.

SURFACE PREPARATION AND APPLICATION

Deicing materials used on roadways can contaminate steel bridges with corrosive salts. Significant chloride concentrations can build up on the top surfaces of beam-bottom flanges and other structural components. To maximize the life of the overcoat system, it is important that the concentration of chemically or reactive foreign materials—such as corrosive and hygroscopic salts—be lowered to threshold levels below which they cause no premature failure of the newly applied system.¹⁰ A good rule of thumb is to measure the efficiency of chloride removal at the identified areas of worst chloride accumulation, ensuring that residual chloride levels are no greater than $10 \mu\text{g}/\text{cm}^2$ —and preferably $<5 \mu\text{g}/\text{cm}^2$.

The surface preparation involved in successful overcoat applications invariably is conducted in accordance with SSPC low-pressure water cleaning methods at 3,500 to 5,000 psi (24 to 34 MPa) (with a turbo nozzle or 0-degree spinner tip held 6 in. [15.2 cm] from the surface) and subsequent power tool cleaning (SSPC SP 3¹¹ or rotary peening SSPC SP 11¹²).

Pressure washing can also be done with specialized soluble salt removers or water-based cleaners: the latter aids salt removal and promotes greater adhesion to the old coating system. High-pressure water cleaning or ultrahigh-pressure waterjetting can also be used.

The lead-contaminated water and removed coatings are subject to collection and disposal. According to the U.S. Environmental Protection Agency (EPA) Toxicity Characteristic Leaching Procedure, if >5 ppm leachable lead is found in the waste material tested, then the latter must be treated and disposed of in accordance with EPA requirements under U.S. Code of Federal Regulations (CFR) Title 40, Parts 261, 262, and 263.¹³

It is important to ensure that the edges of intact paint are feathered back, do not have a ragged appearance,

and are tightly adhered (cannot be removed with a dull putty knife). The bare areas are then primed with overcoat primer and the entire surface coated with either a finish coat or intermediate/finish coat system.

In an overcoat project, it is crucial that the coating film thicknesses are within the ranges specified. Intercoat contamination must not occur, and recoat intervals must be within the manufacturers' acceptable limits.

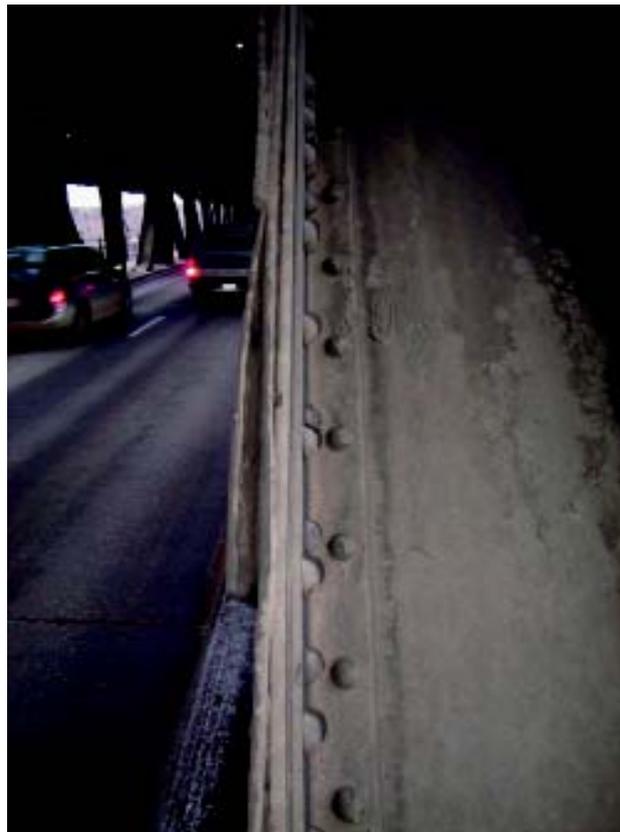
COATING SELECTION CRITERIA AND TESTING

Penetration, wetting, adhesion, minimal shrinkage stress, and flexibility arguably are the most important characteristics of a good overcoat system. Wetting occurs, in part, by polar attraction and lowering surface tension. It is advantageous if the primer concomitantly reacts with, or displaces, moisture.

According to ASTM D907,¹⁴ adhesion is "the state in which two surfaces are held together by interfacial forces which may consist of valence forces or interlocking action or both." Adhesion of a primer to rust and the consolidation of the rust-steel interface correlate strongly, but not exclusively, to the viscosity of the material.¹⁵ Although the best penetration and wicking (capillary) action of overcoat primers was identified with the lowest-viscosity 100% solids epoxy, no primer could completely impregnate and bind all loose rust surfaces.

Sudden freezing conditions can cause the unexpected demise of the

FIGURE 7

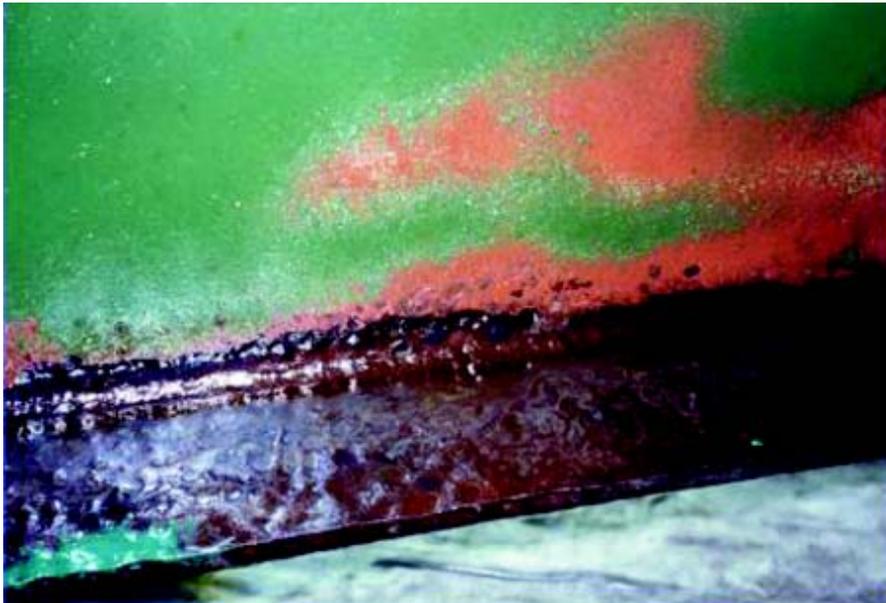


A RAVCS coating on a rusted bridge joint did not fail after 7 years. Photo courtesy of Termarust Technologies.

overcoat system as the finish coat delaminates. Although the condition of the new coating system may initially appear good, one or more freeze-thaw cycles can destroy overcoat systems. The concern is not the amplitude of the temperature transition but the rapidity of the temperature transition and its effect on a poorly adhered and/or stressed overcoat system.¹⁶ Also, if the finish coat had been applied after the recoat interval had elapsed for the intermediate coat, then it has a compromised adhesion that can be overcome later in the cold winter by extrinsic hygrothermal stress. Hence, from an applicator's perspective it is essential to apply coatings within recoat interval requirements.

Equally important from a formulator's perspective is the necessity to balance the intrinsic coating stress of the overcoat system so that it does not detach or rip apart the underlying paint

FIGURE 8



A clear epoxy penetrant sealer was used to overcoat the old alkyd topcoat (green), the old lead primer (red), and pitted/rusted steel. After application of the sealer, epoxy and urethane were applied. Photo courtesy of ICI Devco Coatings.

on the bridge. For example, in a three-coat system Korobou and Salem noted that the tensile strength of the primer should be greater than or equal to that of the intermediate coat, which in turn should be greater than or equal to that of the finish coat.¹⁷

Overcoating often involves large, rusted bridge sections (Figure 7). To achieve optimum functioning of the overcoat system, consider several desirable properties of the overcoat primer:

- Wide compatibility with generically different coatings (especially alkyds)
- Good performance over hand, power tool, and water-jetted surfaces
- Proven long-term success
- Significant penetration into voids and surface imperfections of the old coating
- Penetrant material has sufficiently high pH to neutralize acidity in pack rust
- High degree of wetting, adhesion, and capillary action (low viscosity)
- High-volume solids and, preferably, 100% solids (solvent-free)—no lifting of old coating edges

- Good barrier properties
- Unpigmented; zero or low shrinkage during cure
- Penetrant sealer remains wet for a prolonged period prior to cure
- Moisture-tolerant and able to displace or react with water; carefully balanced rate of cure
- Flexibility
- Low-temperature cure
- Optimal application (brush, roller, and spray) and flow characteristics
- Minimal stress at the substrate-coating interface
- Resistance to hygrothermal stress
- Capability of rust consolidation; rust inhibition
- Low DFT
- Ultraviolet resistance
- Applicator and environmental friendliness.

Clearly, no one coating or coating type completely satisfies this list. Track records should be one of the first selection considerations for overcoat systems. It should be noted that in the U.S., the Northeast Protective Coating Committee (NEPCOAT) is presently undertaking a multifaceted study of

overcoating systems in order to develop an overcoat qualified product list.¹⁸

Overcoating: Some Options

RAVCS PENETRANTS AND PRIMER/TOPCOATS

Several years ago, coating systems using wax and calcium sulfonate were rather soft because of the waxy medium; therefore, both substances were susceptible to mechanical damage and high dirt retention. Furthermore, although single-component, they were not particularly applicator-friendly. There have since been major improvements with the advent of polymer-modified RAVCS coatings. These coatings, sometimes referred to in the literature as “polymer-modified calcium sulfonates,” are much firmer than their wax-based predecessors.

The new generation of RAVCS coatings provides excellent performance for overcoat applications on lead-based paints or when applied to abrasive blasted-steel structures. From both a practical and technical perspective, RAVCS-complex coatings displace water, neutralize surface acidity, and give good adhesion when applied to a suitable substrate.

Low-viscosity RAVCS penetrant sealer possesses useful properties because they soak into pack-rusted joints and connections. The low-pH (~1.8) hydrochloric acid (HCl) present in the rust (formed in the oxidation of steel in the presence of iron chloride [FeCl₃]) is neutralized by the high pH (~10) of the sealer. The sealer may never dry completely and remains active for years; this is beneficial on joints and connections, especially on railway bridges that deflect ≤4 in. (10 cm) with each passing train.¹⁹

PENETRANT-SEALER EPOXIES AND HIGH-BUILD EPOXY MASTICS

To maximize the penetration, wetting, and capillary action of the two-component overcoat primer and to

TABLE 1

LIST OF CANDIDATE COATINGS AND PROPERTIES

Coating Code	Viscosity Ford #4 Cup(s) ASTM D1200 ²³	Generic Type	Volume Solids	Lowest Temperature	
				F	(C)
A	13	EPS	100	50	(10)
B	17	EPS	100	25	(4)
C	334	EPS	100	32	(0)
D	54	EPS	100	50	(10)
E	49	EPS	98	20	(-7)
G	180	MCU-PS	61	20	(-7)
H	63	MCU-PS	61	20	(-7)
J	43	Epoxy-HB	68	0	(-18)
K	21	RAVCS-PS	45	50	(10)

EPS = Epoxy penetrant sealer

MCU-PS = Moisture cured urethane—penetrant sealer

RAVCS-PS = Reacted alkaline viscolastic calcium sulfonate—penetrant sealer

Coatings A-J were tested as reported in ref. 15

Data for K courtesy of Paul Morrison²⁴

provide deep penetration on tight rust and into surface imperfections on existing coatings, several solvent-free epoxy coatings have been formulated to offer viscosities of <30 s in a #4 Ford Cup (Table 1). One of the epoxy-penetrant sealers has a viscosity approaching that of water, 13 and 7 s, respectively.¹⁵ Because the penetrating sealers are very thin, the risk of applying overly thick films to old lead-based paint is eliminated. Also, there are no solvents that can engorge old and solvent-susceptible coatings. Consequently, minimal stresses are imparted by such thin films to the old coating system. When the viscosity of an overcoat primer is >50 s in a #4 Ford Cup, the penetration is markedly lower.

The best epoxy penetrant sealers can cocoon difficult-to-coat areas such as lacing bars. Aside from their ultralow viscosity (Table 1) and favorable surface tensions, well-formulated epoxy penetrant sealers have reasonably high basicity (pH 12), which enable them to respectively soak into pack-rusted joints on bridges and neutralize the HCl in the rust matrix. These epoxy penetrant sealers are tolerant of 100% humidity and can react with, or displace, surface moisture on the bridge.

Direct application of epoxy high-build mastics as overcoat systems can be problematic, however. Although hygrothermal stress-induced overcoat failures might be averted if the film build of the epoxy mastic is kept low, there is real danger if overly thick films are applied. Sooner or later the epoxy mastic in such areas can crack, split the underlying coating(s), and thereby re-expose lead-based primers. Excessive film thickness will exert strong contractive curing forces on multiple layers of an existing lead system. If the latter was originally applied to mill scale, and the adhesion is poor, then the overcoat system can experience premature failure.

It is hard to dispel the concern that direct application of high-build epoxy mastics can lead to poor overcoat per-

formance. In the realm of overcoating, the higher the cross-link density of the epoxy, the higher the chance for it to suffer a stress-induced failure when directly applied to the old coating system.

For aesthetic purposes, an aliphatic polyurethane is invariably used as a finish coat in overcoat systems that use epoxy-penetrant sealers or high-build epoxy mastic primers.

MOISTURE-CURED URETHANES

Moisture-cured urethanes are often favored as penetrating sealers in overcoat projects. Not only do they have excellent adhesion to tight rust and aged coatings, they have performed well in accelerated laboratory tests.²⁰

In a multistage reaction, the isocyanate groups react with water vapor in the air to form polymers with substituted urea linkages. Carbon dioxide (CO₂) is released during cross-linking. This generally is not troublesome unless the film is applied too heavily; if this happens, bubbling can occur and the film formed can have numerous voids, exhibit poor cohesive strength, and have lower service life. The upper film build limit of most moisture-cured urethanes is 4 mils (102 μm) DFT.

Key practical advantages of moisture-cured urethanes include: a) single component (no chance of off-ratio mixes), b) extended recoat times, c) can be applied to damp surfaces in high humidity, and d) are not subject to dew-point

requirements. They are said to possess an inherent ability to react with water on damp surfaces and have good low-temperature cure (20°F [-7°C]) properties.²¹ However, a caveat is that at low temperatures (e.g., 30°F [1°C]) there is much less moisture in the cold air as compared with warm air and, therefore, the reaction rate of a moisture-cured urethane drops accordingly.²²

Conclusions

- The inherent risks of overcoating lead-based paint on bridges can be substantially lowered by judiciously testing and selecting the overcoat system.
- Successful overcoating can be achieved with materials such as solventless epoxy penetrant sealers, moisture-cured urethanes, and RAVCS coatings.
- A penetrant sealer consisting of a block-amine epoxy had the lowest viscosity, followed by a RAVCS and moisture-cured urethane. Ultralow viscosity significantly aids their penetrant-sealing properties. All of these sealers have shown outstanding performance in independent tests.

References

1. H.E. Hower, "Survey of Overcoating Products, Special Report: Overcoating Lead Paint," JPCL (November 1993).
2. B.R. Appleman, E. Kline, J. Eckert, S. Semanderes, SSPC Training Program: Specifications for Overcoating Lead Based Paint (1994).

3. R.B. Meade, T. Hopwood, The Kentucky Bridge Overcoating Program, The Proceedings of the SSPC 1998 Seminars (1998), p. 26.
4. E.S. Kline, W.D. Corbett, "Beneficial Procrastination: Delaying Lead Paint Removal Projects by Upgrading the Coating System," JPCL (1992).
5. A. Forsgren, "Overcoating Lead-Based Paint," PCE (2001): pp. 49-53.
6. SSPC Vis 2, "Guide to Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces" (Pittsburgh, PA: SSPC, 1982).
7. M. O'Donoghue, R. Garrett, R. Graham, V.J. Datta, S. Vitomir, D. White, L. Peer, R. Jones Christoffersen, "Chemical Strippers and Surface-Tolerant Coatings: A Tandem Approach for Steel and Concrete," JPCL 17, 5 (2000), pp. 74-93.
8. ASTM D3359, "Standard Test Methods for Measuring Adhesion by Tape Test" (West Conshohocken, PA: ASTM, 1997).
9. ASTM D5064, "Standard Practice for Conducting a Patch Test to Assess Coating Compatibility" (West Conshohocken, PA: ASTM, 1995).
10. E.S. Kline, C.A. Angeloff, "Rapid Development: A Potential Approach to Reducing the Costs of Painting Steel Overpass Bridges over Busy Highways," JPCL (2000).
11. SSPC SP 3, "Power Tool Cleaning" (Pittsburgh, PA: SSPC, 1995).
12. SSPC SP 11, "Power Tool Cleaning to Bare Metal" (Pittsburgh, PA: SSPC, 1995).
13. U.S. Code of Federal Regulations (CFR) Title 40, "Protection of Environment," Parts 261, 262, and 263 (Washington, D.C.: Office of the Federal Register, 1995).
14. ASTM D907, "Standard Terminology of Adhesives" (West Conshohocken, PA: ASTM, 1996).
15. M. O'Donoghue, R. Garrett, R. Graham, V.J. Datta, L. Peer, "Penetrating Sealers: A Comparison of Epoxy, Moisture-Cured Urethane, and Siloxane Technology on Concrete, Rust, and an Inorganic Zinc Coating," JPCL 15, 12 (1998), pp. 30-47.
16. C. Hare, Clive Hare Associates Ltd., correspondence to author, March 2001.
17. Y. Korobou, L. Salem, Stress Analysis as a Tool in Coatings Research, MP 29, 4 (1990), pp. 30-35.
18. D. Dubois, "Testing Coatings for Bridges: An Update on NEPCOAT," JPCL (January 2001): pp. 49-52.
19. W. Senick, Termarust Technologies, correspondence to author, May 2000.
- 20(a). J. Inch, Powertech Labs. Inc., "Test Program to Approve Paint Systems for use on Steel Highway Bridges and other Structures," 1994. 20(b). T. McManus, correspondence to author, May 2001.
21. N.R. Voigt, "Evaluation of Overcoat Options for Bridge Maintenance Painting," SSPC (1997).
22. C. Hare, Protective Coatings: Fundamentals of Chemistry and Composition, SSPC 94-17 (Pittsburgh, PA: Technology Publishing Co., 1994), pp. 239-266.
23. ASTM D1200, "Standard Test Method for Viscosity by Ford Viscosity Cup" (West Conshohocken, PA: ASTM, 1994).
24. P.E. Morrison, Diverse Applications for Crystalline Calcium Sulfonate Coating Systems in Challenging Environments, SSPC (1997).

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